

Evaluation of the Handheld GLOBE Sun Photometer as a Classroom Resource



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Background

During the summer, multiple handheld sun photometers were evaluated for use in classrooms with close correspondence to the Global Learning and Observations to Benefit the Environment (GLOBE) program. The GLOBE sun photometer, designed by Dr. David Brooks of Drexel University, was first implemented in 2001 in classrooms and communities in multiple Africa countries. Although a plethora of new handheld sun photometers with more sophisticated interfaces have been developed by various organization worldwide, the GLOBE sun photometer remains the most cost effective handheld instrument and consistently provides measurements comparable to those of research-grade instruments.

Atmospheric Aerosols

Atmospheric aerosols can adversely affect human health and influence regional and global weather cycles. PM-2.5, atmospheric aerosols measuring less than 2.5 micrometers, is one of the six criteria pollutants closely monitored by the Environmental Protection Agency due to its health risk when inhaled. Aerosols may enter the atmosphere from natural sources (forest fires, volcanos, deserts, etc.) or anthropogenic sources (power plants, vehicles, pesticides, etc.). Using photometric techniques, ground-based and handheld instruments are capable of measuring the scattering properties of aerosols. The derived value, the aerosol optical depth (AOD), has a variety of applications in earth and environmental science, such as monitoring the transport and fate of aerosols and assessing air quality.

Methods

Every 15 minutes, weather permitting, measurements were taken with two GLOBE sun photometers directly in front of the Science Directorate at NASA Langley Research Center (37.0958, -76.3885) and compared with measurements by AERONET, a research-grade instrument located at the CAPABLE site on center (37.3871, -76.3871). Three raw voltage readings on each channel (505 nm and 625 nm) were recorded and averaged to give one distinct data point for each wavelength. Exact time and GPS location for each measurement was provided by the ExifWizard phone application. Data was reported from 12:00 to 15:00 UTC as GLOBE Aerosols protocol indicates measurements are best prior to solar noon. A spreadsheet provided by Dr. David Brooks was modified in order to convert the raw voltage into AOD.

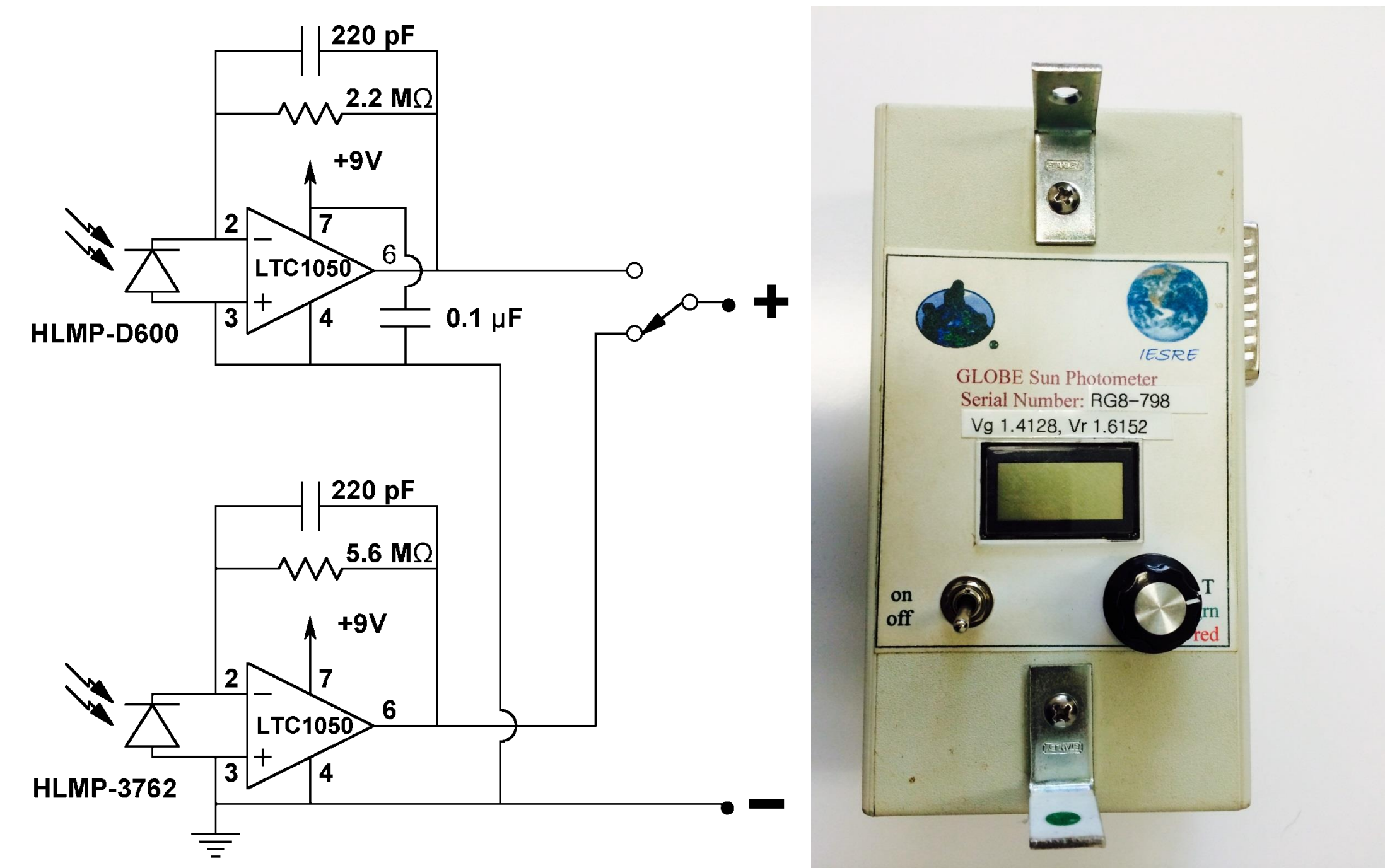
AOD was calculated using the following equation:

$$AOD = [\ln(V_o/R^2) - \ln(V - V_{dark}) - a_R(p/p_o)m]/m$$

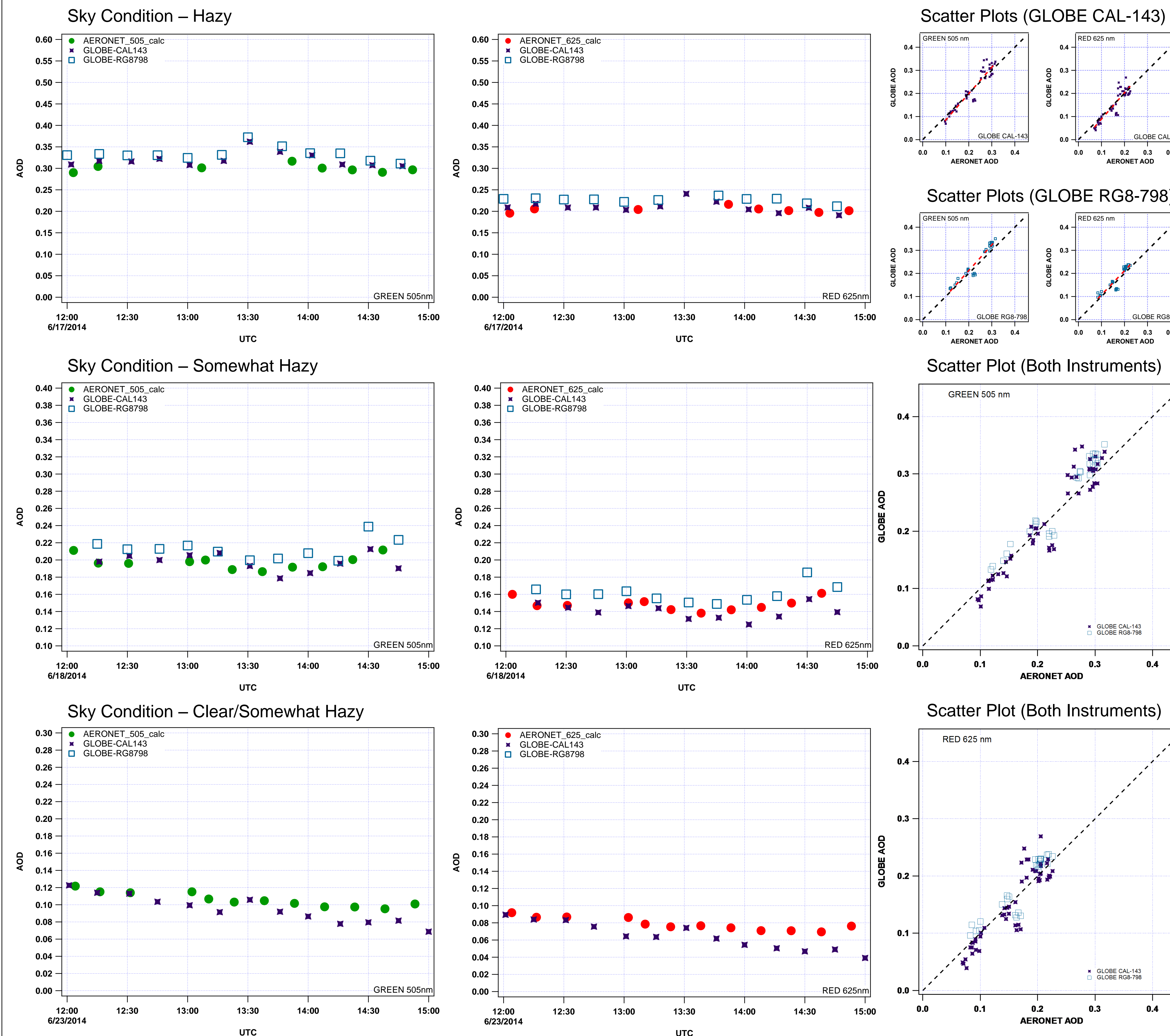
where V_o is the calibration constant of the instrument, V is the raw voltage reading, V_{dark} is the raw voltage reading when the sensor is covered, R is the average Earth-Sun distance, a_R is the Rayleigh scattering coefficient at a particular wavelength, p is the pressure at measurement site, p_o is pressure at STP, and m is the air mass.

GLOBE sun photometer measurements within the range of (+/-) 7 minutes of AERONET were statistically compared by a linear regression between the two AOD values.

GLOBE Sun Photometer Schematic & Instrument



Quantitative Evaluation of the GLOBE Sun Photometer



Due to unfavorable weather conditions throughout the summer, only 18 full days of measurements were collected. Overall, there were 175 measurements at each wavelength for GLOBE sun photometer RG8-798 and 252 measurements at each wavelength for GLOBE sun photometer CAL-143. For the two handheld instruments, 100 and 131 points at each wavelength respectively aligned with AERONET in the range of (+/-) 7 minutes. This was a generous interval that may not be reflective of the actual accuracy of each device. If this interval was reduced to (+/-) 5 minutes, over half of the points in the (+/-) 7 minute interval would be removed.

The three select days provide a snapshot of a gradual decrease in aerosol optical depth over the course of one week (Thursday – Wednesday). There is very high agreement between both instruments and AERONET. However, there are apparent systematic differences between the two instruments. GLOBE sun photometer CAL-143 consistently measured below that of GLOBE sun photometer RG8-798, and as the summer progressed, CAL-143 consistently measured below AERONET, as it begins to do on 6/23/2014.

AOD for AERONET must be calculated at the desired wavelength to match that of the GLOBE sun photometers (505 nm and 625 nm). AERONET measures at 500 nm and 675 nm, among other wavelengths, and must be converted to match the desired wavelengths of 505 nm and 625 nm. This conversion can be accomplished using the angstrom exponent, where $\tau_\lambda/\tau_o = (\lambda/\lambda_o)^{-\alpha}$ and $-\log(\tau_\lambda/\tau_\lambda)/\log(\lambda_1/\lambda_2)$. In this equation, τ_λ is the AOD at a wavelength λ and τ_o is the AOD at the reference wavelength λ_o .

A summary of the sky conditions and corresponding AOD values can be found in Table 1. Throughout the summer, sky conditions did not dip into the “Extremely Clear” category or exceed the “Hazy” category. A majority of the measurements were classified as “Somewhat Hazy” with very few measurements entering the “Clear” or “Hazy” range.

Table 1. Summary of Sky Conditions

Sky Conditions	Green Channel (505 nm)	Red Channel (625 nm)
Extremely Clear	0.03-0.05	0.02-0.03
Clear	0.05-0.10	0.03-0.07
Somewhat hazy	0.10-0.25	0.07-0.20
Hazy	0.25-0.50	0.20-0.40

Long-term Engagement in Authentic Research with NASA (LEARN) Program

The Long-term Engagement in Authentic Research with NASA (LEARN) program began in Summer 2012. The program selects highly qualified and motivated middle and high school science teachers from across the country and gives them the resources and guidance to more effectively introduce science to their students through hands-on science activities and NASA educational material. For two weeks in July, new and returning teachers are brought on-site at NASA Langley Research Center. Newly selected teachers begin the year-long program with a three day GLOBE workshop at NASA Langley Research Center covering all of GLOBE atmospheric protocols. The remainder of the two week session is devoted to data gathering and interpretation with guest lectures from NASA scientists. Teachers have the remainder of the year to research a topic and are expected to present a poster the following summer.

Since its founding, nineteen teachers have been involved in the LEARN program, with three teachers from Cohort 1 and four teachers from Cohort 2 entering the third year of the program. The program is not only rewarding to the teachers involved, but also to their students, who benefit directly from gathering and analyzing data obtained by handheld instruments or through the NASA and GLOBE educational programs.

LEARN Summer 2014



Pictured:
Samantha Adams
Kathleen Breen
Robert Bujosa
Stephen Haggard
Jodie Harnden
Denise Magrini
Chris Marentette
Cara Moulton
Melissa Niemi
Dr. Margaret Pippin
Patricia Pitton
Gay Reilly
Angela Rizzi
Eric Thuma
Jeff Timmerman

Not Pictured:
Ellen Babcock
Sue Dougherty
Sue Meinch
Dr. Ali Omar
Dr. Melissa Yang

Conclusion

Handheld sun photometers are an invaluable tool for education, as these instruments can foster a greater understanding and appreciation of the environment in students and communities worldwide. Both students and teachers can benefit from this hands-on science and learn in a manner that textbooks alone cannot provide. For the upcoming year school year, there are plans in progress to construct and calibrate GLOBE sun photometers in a classroom setting with collaborations between LEARN teachers and their students.

Acknowledgements

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References

Brooks, D. R., & Mims III, F. M. (2001). Development of an inexpensive handheld led-based sun photometer for the globe program. Journal of Geophysical Research, 106(D5), 4733-4740.

GLOBE. (2005). Aerosols protocol. Atmosphere, Retrieved from <https://www.globe.gov/documents/348614/348678/aerosol.pdf>